Heart Rate Changes Associated with

Stuttered and Fluent Speech

Michele Rogers

Northern Illinois University

Howard D. Schwartz

Academic Advisor

Approved: Howard Schwartz
Howard Schwartz

Department of: Communicative Disorders

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Abstract

Emotional reactions during stuttering have been examined using various techniques (e.g. patient reports of anxiety, patient questionnaires) (Brutten 1975). These measures are often subjective and difficult to define. In the present study the heart rates of stuttering and fluent adults were examined during various speech and nonspeech tasks in an attempt to objectively examine emotional reactions during speech. Resul ts of the present investigation indicated that adult stutterers exhibited faster absolute heart rates that were more stable when compared to the normally fluent adults. These heart rate characterisitcs were similar to those reported by Kagan, Reznick, and Snidman (1988) who examined behaviorally inhibited children. Results suggested a possible relationship between heart rates, stuttering and learned behavioral inhibition.

Stuttering development has been related to a child's speech abilities, the communicative environment and the child's awareness of, and reactions to, his speech and the environment. Speech abilities have been examined in a variety of ways that relate to laryngeal function and speech rate. Conture (1982) described the development of stuttering in terms of laryngeal adjustments. He suggested that reactions to laryngeal and articulatory behaviors resulted in a child producing different stuttering types. Darley (1978) examined rate of speech production and concluded that adult stutterers exhibit rates of speech that differ significantly when compared to fluent adults. Factors in the communicative environment have been shown to influence the development of stuttering. Meyers and Freeman (1985) examined the relationship between parental rate of speech and stuttering and concluded that parental rate of speech affected the development of stuttering and should be considered for identifying and treating stuttering. Zebrowski (1987) also examined environmental influences by examining parental perceptions of stuttering. Zebrowski concluded that parental perception of stuttering was affected by the duration and type of stuttering and should be considered when examining stuttering development. Awareness and reactions to stuttering has been the least explored area of stuttering development. Giolas and Williams (1958) determined that some children in kindergarten were able to identify stuttering in a recording of an adult stutterer. Schwartz and Conture (1988) suggested that those children who exhibit sound prolongations and increased number and variety of associated behaviors are more aware and may be more at risk for the continued development of stuttering. Although some investigators have examined awareness and reactions during stuttering, a lack of objective evidence exists that quantify emotional reactions during stuttering. While numerous studies exist that examine a stutterer's speech abilities, and research and clinical reports examine the affects of the communicative environment, the aforementioned studies are only two of a paucity of research that focus on a stutterer's reactions during stuttering.

As early as 1890, James and Lange suggested that emotions are the perception of bodily reactions. The relationship between bodily reactions and emotions of children and adults have been investigated in a number of ways. These investigations have included studies of skin conductance (e.g., Lewis & Smith 1987), blood pressure (e.g., Hokanson & Burgess, 1962») chemical levels in the blood (e.g., Sahachter & Singer, 1962») and heart rates (e.g., Hokanson & Burgess). While all of the aforementioned reactions provided information regarding emotional responses, heart rate changes have been shown to be most reliable over time (Lacey, 1962).

Various studies have examined the heart rates of children and adults. Heart rate changes have been examined during changing emotional states. Ekman, Levanson, and Friesen (1978) examined heart rate changes while adults relived or positioned their facial muscles in various emotional expressions (e.g. happiness, anger). These investigators found that specific heart rate changes were related to specific facial expressions. Campos, Emde, Gaenbauer, and Henderson (1975) examined infant heart rates during changing facial expression, and reported that infant's facial expression changed from interested to fearful upon the entrance of a stranger with associated heart rate acceleration. Heart rate changes have also been examined to determine the stability of individual differences over time. Kagan, Reznick, and Snidman (1988) examined the heart rates of inhibited children and found that inhibited behavior was typically associated with a higher and more stable heart rates across situations over time. Manuck and Schaefer (1978) demonstrated adults exhibited consistent heart rate changes seven days apart, and indicated that consistent individual responses in heart rate may suggest individual differences in sympathetic nervous system activity. Thus, measuring heart rates can provide important information about the emotional reactions across situations. While heart rates have been examined in children and adults during various tasks, few studies examining heart rates and emotional reactions of stutterers have been conducted.

Previous research has focused on emotional reactions to stuttering in different ways. Reactions to stuttering have been measured through patient reports of anxiety and patient questionnaires (Brutten 1975). However, these measures are often subjective and lead to problems defining levels of anxiety. Few investigators have examined the relationship between autonomic nervous system activity and stuttering. Kraaimannt, Janssen, & Brutten (1988) examined autonomic responses during verbal tasks and determined a relationship between high skin conductance measures and prognosis for therapy. Peters and

Hulstijn (1984) compared physiologic responses of fluent adults to stuttering adults and found no significant differences in heart rate when examining baseline to task differences. Weber and Smith (1989) showed that greater autonomic arousal occurs prior to spontaneous speech than reading, and that higher autonomic arousal levels are related to disfluent behavior, even in the interval prior to the stuttering. While the aforementioned investigators examined stuttering in a variety of contexts, it would be interesting to examine the changes in heart rate associated with conditions that induce fluency (e.g. metronome, choral reading). Results of this investigation should provide insight into possible emotional changes that may occur during the therapy process.

METHODS

Subjects

Five adult stutterers and five normally fluent adults (matched in age and sex) from the Northern Illinois region participated in this study. These ten subjects ranged in age from 19 years to 69 years. To be included within this study, every adult stutterer had to produce at least three within-word disfluencies (sound/syllable repetitions and sound prolongations) per 100-words of conversational speech. Frequency of stuttering and sound prolongation index (number of prolongations/total number of stutterings) was calculated for each subject. Subjects exhibited a mean frequency of stuttering of 9.8% (range 5%-17%), and a mean sound prolongation index of 41% (range 15%-85%). Every subject was informed about the nature of the experiment prior to participation.

Equipment

A specially modified color video tape recorder (Vetter Model #620) designed to record FM signals, was used to record subject data during each task. The FM recorder enabled the examiner to record the audio(SONY Model ECM 55-B), video, visible time code (Fast Forward Model F-200), and raw pulse signal on a video tape for later analysis.

A finger photoplethysmograph (Med Associates Model #TDE-40) was used to record the raw pulse signal. This device contains an "infrared emitter and a matched photo resistor" that modulated when blood flows through the finger resulting in changes in electrical output (Labtech Manual), The photoplethysmograph was placed on the index finger of each subject's right hand to obtain a raw pulse signal. The raw pulse signal was conditioned (Med Associates Model #ANL-420) and recorded on one channel of the FM recorder (Vetter Model 620).

Procedure for physiologic data collection

Each subject was seated in a comfortable chair that helped prevent extraneous movement. The examiner explained to the subject that he would participate in six tasks during which his/her heart rate would be collected for two-minutes. Prior to each task, the subject's heart rate was collected for a one-minute silent period. This served as a baseline measure relative to the subsequent task. In addition a two- minute baseline was collected prior to, and following the process.

The subjects participated in each of the following tasks:

1) CONVERSATION. Subjects were asked talk about themselves (e.g. job, hobbies).

2) READING. Each subject was instructed to read a passage aloud (see Appendix A).

3) READING WITH A METRONOME. The subject was given a passage (see Appendix B) and instructed to read at one word per beat of the metronome (60 beats per minute).

4) READING SILENTLY TO BEAT OF METRONOME. The subject was given a passage (see Appendix C) and instructed to read one word per beat of the metronome, silently to himself.

5) CHORAL READING. Examiner explained that both she and the subject would be reading the fourth passage (see Appendix D). Subject was instructed to join in and read along with examiner as soon as the examiner began to read.

6) ANALYTICAL TASK. Examiner explained that the subject would be computing an addition problem with 21, 2 and 3 digit numbers. Subjects were instructed that the examiner was not measuring accuracy of answers, but interested in

the heart rate during process of trying to compute the problem.

These six tasks were randomly presented to each subject with each subject pair (fluent-stuttering subject) completing the tasks in the same order.

Data Analysis

The raw pulse signal was transmitted to a DASH-16/16F (Metrobyte) digitizing board housed in a Zenith computer (Model Z-248-12). The DASH-16 board was used by data analysis software (LABTECH Notebook) to digitize the pulse signal (20Hz) and calculate the mean interbeat interval and standard deviation for each task. The software was programmed to calculate the mean IBI during each baseline with instructions to subtract the mean IBI for each task to determine a difference value relative to each baseline (Baseline-MIBI=Difference). In addition, the software was programmed to calculate the mean standard deviation of the IBI's collected during 30-seconds of each task.

The mean IBI was obtained during the 60-90 second period during the initial baseline recording, during each task, and during the final baseline. The IBI during each one-minute baseline prior to each task was obtained during the 30-60 second period.

RESULTS

This investigation examined the raw pulse data of fluent and stuttering adults. The mean interbeat interval (IBI) in ms and standard deviation (e.g. variablilty from period to period), that characterized each 30 second baseline period and each 30 second task was examined. The following tasks were examined: RW reading with a metronome, CON conversation, RSM reading silently with metronome, CR choral reading, R reading, and AT analytical task.

Examination of mean group difference values (baseline-task) (see Table 1), multivariate T-test, Hotelling-Lawley Trace = 3.696 (F-value = 1.848, df = 6,3, $P > .03$) indicated no significant differences. Table 1 also presents univariate test results that indicated no significant differences.

Examination of mean IBI data (see Table 2) revealed that stutterers exhibited faster heart rates than normally fluent speakers during all tasks. Multivariate test results indicated significant differences ($F = 47.140$, df = 6,3, $p < .01$). Table 2 presents the mean IBI collected during each task and univariate p - values for each task.

Examination of mean standard deviation of IBI's (see Table 3) revealed that stutterers consistently exhibited less variability of heart rate associated with their mean IBI for each task. Multivariate test results indicated significant differences ($F = 11.413$, df = 6,3, $p < .036$). Table 3 presents the mean standard deviation of IBI collected during each task and univariate p - values indicating significant results for each task.

DISCUSSION

The purpose of this study was to examine heart rate changes of stuttering adults and fluent adults between and across various speech and nonspeech tasks. Results were consistent with Peters and Hulstijn (1984) findings which indicated no significant differences in heart rate when examining baseline to task differences across groups.

Analysis of heart rates during individual tasks and heart rate variability during each task revealed significant differences between the fluent and stuttering adults. The adult stutterers exhibited faster and more stable heart rates across tasks. The more stable heart rates exhibited by the stuttering adults in this study, were not consistent with Weber and Smith (1988), who demonstrated that both fluent and stuttering adults reported variable heart rates across tasks. However, the present results may be affected by the number of subjects in the study or differences in subject selection procedures.

A number of investigators have suggested a relationship between behavioral inhibition and heart rate variability (Kagan and Moss, 1962; Kagan, Reznick, and Snidman 1988). Kagan (1988) reported children who demonstrated more stable, less variable heart rates exhibited the following: demonstrated long latencies to initiate play or interact with an unfamiliar child, isolated themselves, infrequently interacted with classmates in the child's school setting, demonstrated long latencies to talk and infrequent spontaneous comments with a female examiner, and exhibited reluctance to play with novel toys. Thus, it may be possible that adult stutterers learn to respond to environmental stimuli in a manner that is typical of the behaviorally inhibited child. As a result, these adults exhibit less variability and perhaps less flexibility in being able to respond to emotional stimuli. For example, an adult stutterer confronted with a difficult speaking situation may not enter into this situation which in turn limits his abilities to respond emotionally. A clinician will need to be aware of these limitations as a portion of the therapy program should be directed toward client counseling and increasing a client's options for emotional responding.

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Table 1: Mean difference values (baseline - task) for stutterers verses nonstutterers during each of the following tasks: RW reading with metronome, CON conversation, RSM reading silently with metronome, CR choral reading, R reading, AT analytical task. Univariate test results follow indicating no significant differences.

	RW	CON	RSM	CR	R	AT
Group 1	-0.002	0.029	-0.010	0.120	0.049	0.072
Group 2	0.049	0.135	-0.025	0.032	0.095	0.051
UNIVARIATE P - values	0.409	0.170	0.773	0.319	0.442	0.743

Table 2: Mean Interbeat intervals collected during 30 seconds of each of the following tasks: RW reading with metronome, CON conversation, RSM reading silently with metronome, CR choral reading, R reading, AT analytical task. Univariate test results follow indicating significant group differences.

	RW	CON	RSM	CR	R	AT
GROUP 1	0.564	0.524	0.573	0.526	0.504	0.572
GROUP 2	0.879	0.828	0.986	0.877	0.822	0.852
UNIVARIATE P - values	0.007	0.001	0.004	0.004	0.007	0.036

Table 3: Mean Standard Deviation of Interbeat Intervals (in ms) collected during 30 seconds of each of the following tasks: RW reading with metronome, CON conversation, RSM reading silently with metronome, CR choral reading, R reading, AT analytical task. Univariate test results follow indicating significant group differences.

	RW	CON	RSM	CR	R	AT
GROUP 1	0.105	0.104	0.098	0.099	0.098	0.080
GROUP 2	0.229	0.184	0.255	0.207	0.169	0.223
UNIVARIATE P-values	0.004	0.000	0.002	0.042	0.057	0.006

Appendix A - Choral Reading Passage

The theory of plate tectonics describes the motions of the Iithosphere, the comparatively rigid outer layer of the earth that includes all the crust and part of the underlying mantle. The lithosphere is divided into a few dozen plates of various sizes and shapes; in general the plates are in motion with respect to one another. A mid-ocean ridge is a boundary between plates where new lithospheric material is injected from below. As the plates diverge from a mid-ocean ridge they slide on a more yielding layer at the base of the lithosphere.

Since the size of the earth is essentially constant, new Iithosphere can be created at the mid-ocean ridges only if an equal amount of lithospheric material is consumed elsewhere. The site of this destruction is another kind of plate boundary: a subduction zone. There one plate dives under another and is reincorporated into the mantle. Both kinds of plated boundary are associated with fault systems, earthquakes and volcanism, but the kinds of geologic activity observed at the two boundaries are quite different.

The idea of sea-floor spreading actually preceded the theory of plate tectonics. The sea-floor spreading hypothesis was formulated chiefly by Harry H. Hess of Princeton University in the early 1960's. In its original version it described the creation and destruction of ocean floor, but it did not specify rigid lithospheric plates. The hypothesis was soon substantiated by the discovery that periodic reversals of the earth's magnetic field are recorded in the oceanic crust. An explanation of this process devised by F.J. Vine and D.H. Matthews of Princeton is now generally accepted. As magma rises under the mid-ocean ridge, ferromagnetic minerals in the magma become magnetized in the direction of the geomagnetic field. When the magma cools and solidifies, the direction and the polarity of the field are preserved in the magnetized volcanic rock. Reversals of the field give rise to a series of magnetic stripes are associated with reversals of the magnetic field that can be dated independently, the width of the stripes running parallel to the axis of the rift. The oceanic crust thus serves as a magnetic tape recording of the history of the geomagnetic field. Because the boundaries between stripes are associated with reversals of the magnetic field that can be dated independently, the width of the stripes indicates the rate of sea-floor spreading. (Precisely how the earth's magnetic field reverses at intervals of from 10,000 to about a million years continues to be one of the great mysteries of geology.)

Appendix B - Reading Task Passage

Rocks which have solidified directly from molten materials are called igneous rocks. Igneous rocks are commonly referred to as primary rocks because they are the original source of material found in sedimentaries and metamorphics. Igneous rocks compose the greater part of the earth's crust, but they are generally covered at the surface by a relatively thin layer of sedimentary or metamorphic rocks. Igneous rocks are distinguished by the following characteristics: (1) they contain no fossils; (2) they have no regular arrangement of layers; and (3) they are nearly always made up of crystals.

Sedimentary rocks are composed largely of minute fragments derived from the disintegration of existing rocks and in some instances from the remains of animals. As sediments are transported, individual fragments are assorted according to size. Distinct layers of such sediments as gravels, sand, and clay build up, as they are deposited by water and occasionally wind. Theses sediments vary in size with the material and the power of the eroding agent. Sedimentary materials are laid down in layers called strata.

When sediments harden into sedimentary rocks, the names applied to them change to indicate the change in physical state, Thus, small stones and gravel cemented together are known as conglomerates; cemented sand becomes sandstone; and hardened clay becomes shale. In addition to these, other sedimentary rocks such as limestone frequently result from the deposition of dissolved material. The ingredient parts are normally precipitated by organic substances, such as shells of clams or hard skeletons of other marine life.

Both igneous and sedimentary rocks may be changed by pressure, heat, solution, or cementing action. When individual grains from existing rocks tend to deform and interlock, they are called metamorphic rocks. For example, granite, and igneous rock, may be metamorphosed into a gneiss or a schist. Limestone, a sedimentary rock, when subjected to heat and pressure may become marble, a metamorphic rock. Shale under pressure becomes slate.

Appendix C - Silent Reading To Metronome Passage

Genetic variation is also important in the evolution of lower organisms such as bacteria, and here too it arises from mutations. Bacteria have only one chromosome, however, so that different alleles or variant forms of a gene are not normally present within a single cell. The reshuffling of bacterial genes therefore ordinarily requires the introduction onto a bacterium of DNA carrying an allele that originated in a different cell. One mechanism accomplishing this interbacterial transfer of genes in nature is transduction: certain viruses that can infect bacterial cells pick up fragments of the bacterial DNA and carry the DNA to other cells in the course of a later infection. In another process, known as transformation, DNA released by cell death or other natural processes simply enters a new cell from the environment by penetrating the cell wall and membrane. A third mechanism, conjugation, involves certain of the self-replicating circular segments of DNA called plasmids, which can be transferred between bacterial cells that are in direct physical contact with each other.

Whether the genetic information is introduced into a bacterial cell by transduction, transformation or conjugation, it must be incorporated into the new host's hereditary apparatus if it is to be propagated as part of that apparatus when the cell divides. As in the case of higher organisms, this incorporation is ordinarily accomplished by the exchange of homologous DNA; the entering gene must have an allelic counterpart in the recipient· DNA. Because homologous recombination requires overall similarity of the two DNA segments, it can take place only between structurally and ancestrally related segments. And so, in bacteria as well as in higher organisms, the generation of genetic variability is limited to what can be attained by exchanges between different alleles of the same genes or between different genes that have stretches of similar nucleotide sequences. This requirement imposes severe constraints on the rate of evolution that can be attained through homologous recombination.

Appendix D - Analytical Task

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  324
  987
  234
   87
  560
  230
   98
  345
  987
  239
  198
   43
  467
  907
  672
   67
  324
  876
  906
  675
+ 875
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